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NON-TUBERCULOUS PYOGENIC OSTEOMYELITIS OF THE SPINE

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Until recently, the spine has been considered a rare site of pyogenic involvement. Its more common recognition in recent years can probably be ascribed to a greater awareness on the part of Clinicians and Radiologists alike, and also to a lowered incidence of tuberculosis which many of these cases may have been considered to be in the past. In our hospital the diagnosis has been made three times as frequently in the last three years as in the previous ten-year period.

Judicious use of modern antibiotics can arrest the destructive process in the majority of cases of pyogenic osteomyelitis[9] and so it is increasingly important to make the diagnosis as early as possible. So that we can offer the greatest assistance to this end, it was considered worth while to review the features of this disease and to make a special study of its early diagnosis and differential diagnosis.

In this study I have reviewed the cases of non-tuberculous osteomyelitis recognized at the Regina General Hospital in the last ten years, and I have attempted to analyze those features which will permit a differentiation from tuberculosis.

TABLE I

PATHOGENESIS

PYOGENIC OSTEOMYELITIS OF THE SPINE

Infecting Organism

Staphylococcus	80 - 90%
Salmonella	10 - 20%
Typhoid	
Paratyphoid	
Brucella	

Any of the common pathogens may be the infecting organism (Table I). In the majority of patients, however, it is the staphylococcus[12,21]. Patients are occasionally seen in which the infecting organism may belong to one of the species of salmonella (including typhoid and paratyphoid) or brucella.

While the nature and characteristics of the pathological process have been known for many years, recent work by Batson[3,4] has provided a better understanding of the source and route of spread of the infecting organism. It is well recognized that the blood flow in the sinusoids of the vertebral trabeculae is slow and that stagnant blood provides favorable circumstances for the implantation and establishment of bacterial foci of infection[8].

Batson's demonstration of the extensive anastomoses of the veins of the vertebral column with those of the walls of the thoracic, abdominal and pelvic cavities has offered a logical explanation for the apparently unrelated high incidence of spine infections following urinary tract infections, tuberculosis of the spine following pulmonary tuberculosis and spinal and cerebral metastases following bronchogenic carcinoma. He described the extensive nature of this venous system and the tendency of pelvic emboli to travel by this route in preference to the caval and portal systems. He showed that this system constitutes a reservoir of blood protected from the fluctuations in pressure of the abdominal and thoracic cavities with resultant flow of blood to and from the vertebral system caused by changes in pressure within the chest and abdomen.

Pathology

The focus of infection, once located and implanted, grows by circumferential expansion[17]. In the early stages before pus formation there is flooding of the tissue with polymorphs, and soon the picture is that of living and dead polymorphs with areas of liquefaction necrosis and cell detritus. Later, the exudate contains lymphocytes, macrophages and plasma cells. Eventually, scarring and fibrosis supervene and it may be difficult to find any exudative cells. The inflammation and necrosis cause destruction of trabeculae with liquefaction of the matrix and pus formation. As the destruction progresses, the

weakened bone may collapse. If the focus is located close to the upper or lower surface of a vertebral body, there may be localized collapse with herniation of the disc into the body. A focus situated peripherally will be more likely to lead to anterior, posterior or lateral collapse with wedging, while a focus centrally placed will progress to a greater extent before collapse will appear.

The bones of the neural arch may also be involved, and destruction of the pedicle may result in forward or lateral slipping of one body on its neighbour. Rupture of the infectious process into the neural canal may result in an epidural abscess with resultant pressure on the spinal cord or nerves[19].

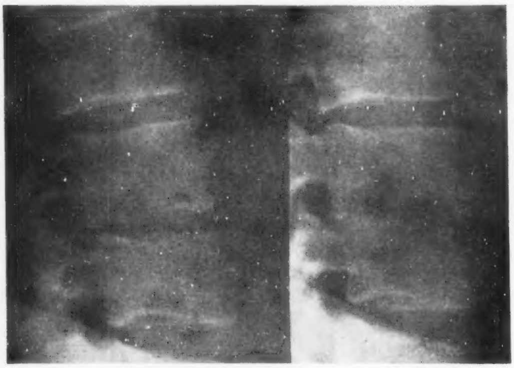

Figure 1 — An example of thinning of the intervertebral disc, the earliest and, when accompanied by bone destruction, the most reliable sign of osteomyelitis of the spinal column.

Except in the very young, there is no blood supply to the disc[17], and dissolution occurs by direct invasion of the disc by infection and is accompanied by herniation of the disc into the weakened body.

Soft tissue extension is not as prominent a feature of this disease as it is of tuberculosis[18], where extensive spread occurs under the ligaments producing large paravertebral abscesses and extension to other vertebral segments. However, less impressive paravertebral abcesses do occur.

Reaction to the infection occurs early and is typically osteoblastic in nature[7]; necrosis and dissolution is accompanied by the production of new bone. This is one of the most reliable indications of the non-tuberculous nature of the disease.

TABLE II
CASE MATERIAL

Cervical	1
Thoracic	3
Lumbar	6
Sacrum	1
Total	11 lesions (in 10 patients)

Case Material (Table II)

Our series of cases consists of ten patients with non-tuberculous pyogenic osteomyelitis of the spine. All are not pathologically proven. However, in view of the subsequent course, progress and response to therapy, the diagnosis seems justified in this group. In these cases there were six lesions in the lumbar region, three in the thoracic region, and one each in the cervical and sacral areas. Two of these lesions were in the same patient in different areas, each of about the same estimated duration.

Radiological Signs

In our group of cases, thinning of the intervertebral disc was the most consistent and reliable sign of the disease. In only one lesion was there no thinning. This was in the thoracic area involving the central portion of the body of T-5. In the remainder, the thinning and destruction of the disc when the case was first seen was extensive in four and moderate in the remaining six. In those cases seen in the earliest phase of the disease, there was loss of definition of the superior or inferior surface of the involved vertebral body in five of the six cases.

Figure 2 — An example of the exuberant bone production which characterizes the healing phase.

A paravertebral soft tissue mass could be demonstrated in seven cases. It was large in two of these; but in the majority it was not impressive and often difficult to demonstrate. Generalized rarefaction of the bone structure was consistently absent from our cases. Involvement of the neural arch if present is a significant feature but this was only demonstrated three times. Bone destruction and collapse is characteristically marked in tuberculous involvement of the

spine. In our cases of non-tuberculous osteomyelitis, bone destruction and collapse varied from none at all to very marked, but in no case was it as extensive as is commonly seen in tuberculosis. It was our conclusion that the degree of destruction was not of much value as a diagnostic feature in itself but when evaluated with other findings it helped to determine the age of the lesion when first seen and thus the rapidity of the progress could be estimated.

Figure 3 — Paravertebral mass associated with pyogenic osteomyelitis (tomogram). Large paravertebral soft tissue shadows are uncommon; it is more usual to identify the paraspinal effects of the infection with difficulty.

Erosion of the anterior or lateral surfaces of the body was present in three lesions, but in only one of these was the character of this feature suggestive of spread under the ligament, as is commonly seen in tuberculosis. In the other cases it appeared to be direct extension from the primary focus. A radiological sign described as bevelling is produced when a corner of a body is destroyed[12]. This is said to be found only in pyogenic involvement of the spine, so that when present it may be of some diagnostic value.

Osteoblastic response and sclerosis were consistently present when examinations were available over a long enough period of time to demonstrate this change. Usually the time interval was a matter of weeks. In eight of the lesions this feature was marked and conclusive. In several of our cases in which observation was possible over a sufficiently long period to evaluate the end stage of the disease, we found a solid bone fusion between two or more segments, usually with some slight deformity. It has been said that involvement of two adjacent vertebral bodies and the intervening disc is a feature of tuberculous infection of the spine[20] but it was present in nine of our eleven cases of non-tuberculous infection; thus the disc does not seem to resist the spread of infection of either etiological group. It was interesting to note that two of our cases were children, but the disease differed in no essential from its behavior in adults.

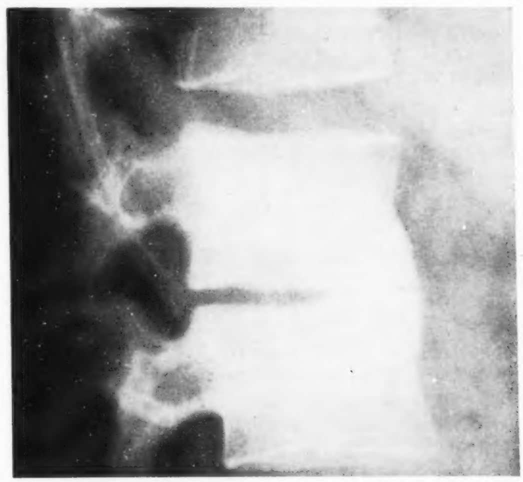

Figure 4 — An example of marked thinning of the disc without demineralization of the adjacent bones. The involved bodies show irregular sclerosis and small destructive foci.

TABLE III
SOURCE OF INFECTION

Lower urinary tract	2
Ear	1
Perinephric Abscess	1
Source not determined	7

Source of Infection (Table III)

In only two of our cases was there a clear-cut history of lower urinary tract infection prior to the onset of the back symptoms, but in two other cases there were infections in other sites that could well have spread via the vertebral system of veins, namely the perinephric region and the post-auricular region.

TABLE IV
DIFFERENTIAL DIAGNOSIS

Tuberculous	Pyogenic
No osteoblastic response.	Marked osteoblastic response.
Large paravertebral abscess.	Small or no paravertebral abscess.
Marked rarefaction.	Less rarefaction.
Slow course.	More rapid course.
Marked destruction and collapse.	Less destruction and collapse.

In the early stages differentiation is impossible.

Differential Diagnosis (Table IV)

Differentiation of the various bacteriological types is difficult and is becoming more difficult as modern antibiotic therapy succeeds in arresting the processes in their earlier phases. Indeed, it may well be that many cases of pyogenic osteomyelitis in the past have been considered to be tuberculous because of incomplete workup and reliance on their radiographic appearance. The comment is repeatedly made in the literature,[9,12,17] that staphylococcic osteomyelitis cannot be differentiated from typhoid, paratyphoid or brucella infections radiologically. The main differentiation then, that needs to be made, is between pyogenic and tuberculous osteomyelitis (Table IV). Since the advent of modern antibiotics, the handling and treatment differ considerably and delay in the institution of suitable therapy can be tragic. Therefore, every effort should be made when the case is first seen to make a correct diagnosis. This becomes more important when one realizes that in many cases it may not be feasible to obtain bacteriological proof. In the early phase of the disease it may be impossible to make this differentiation. At this stage the only valuable feature is the degree of general demineralization of the area which is more marked in tuberculous than in non-tuberculous infection. In an occasional case of neural arch involvement, which is more common in the non-tuberculous group, the location of the focus may assist in the differentiation.

In later phases the differing degree of demineralization is more marked and the added features of paravertebral abscess formation, extension to adjacent segments, degree of bone destruction, and most important, the degree of osteoblastic reaction assist in the differentiation. In all cases a detailed correlation of the radiological age of the lesion with clinical features of the case should be made to evaluate as accurately as possible the rapidity of the course.

Conclusions

Suppurative non-tuberculous osteomyelitis of the vertebral column is more common than has previously been considered. Modern antibiotic therapy can arrest the progress of these early lesions and lead to solid healing with little residual deformity if the treatment is started early in the course of the disease.

The most helpful early radiological signs are decalcification of the superior and inferior surfaces of the vertebral body and diminished definition of the bone margins contiguous to the disc. Later signs include sclerosis and new bone formation, involvement of the neural arch, rapid progress, and final complete fusion.

The most reliable radiological sign of infection of the vertebral body in any stage of its development is thinning of the disc and bone destruction. The most reliable signs to assist in the differentiation of tuberculous from non-tuberculous involvement are sclerosis and new bone formation in the healing phase and rapid progress of the disease in all phases. Early diagnosis will be made more frequently if attention is paid to minor degrees of disc thinning and loss of definition of vertebral body surfaces bordering on the intervertebral discs.

Summary

The pathological and radiological features of non-tuberculous osteomyelitis of the vertebral column have been reviewed and a study has been made of eleven lesions in ten patients seen at the Regina General Hospital in ten years.

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BOOK REVIEW

Roentgen Examinations in Acute Abdominal Diseases, J. Frimann-Dahl, M.D.,Ph.D., Second Edition 1960, Charles C Thomas, Publisher, Springfield, Illinois, $16.50, Pp. 518, with 446 illustrations.

This book, which is now revised for the first time, is one of the most important monographs of Diagnostic Radiology. The author, in a considerable measure, has been responsible for bringing the interpretation of plain radiographs of the abdomen to an orderly discipline. The scheme of the book is a review of normal and general pathological findings in the radiological examination of the abdomen. Then special findings in the important structures or important abnormalities are reviewed in detail. The reviews of the world literature and the additions of the author's experience and often own investigative work are usually excellent and almost all the problems of acute abdominal disease are covered in every age group. The approach in cases in which there is diagnostic uncertainty or when conservative therapy is planned is to promptly secure very good radiographs and to interpret them immediately in the presence of the attending physician. This integration of clinical and radiological disciplines has helped greatly in achieving the reduced morbidity and mortality in the acute abdomen.

The first edition was an exciting book because the reader became more fully aware of the power of the diagnostic tool. The second edition is all of this plus the addition of new knowledge and improved writing which is a pleasure to read.

D.M.E.

Manual of Radiation Therapy, K. Whilhelm Stenstrom, Ph.D.; 94 pages, 5 illustrations; Charles C Thomas, Publisher, 1957.

This book, according to its cover, is presented as a teaching guide for graduate students in radiology, and a book of considerable interest to the practicing general radiologist. The first part is entitled "Basic Elements of Radiation Therapy." In it, physics, protection, chemistry, and biology are briefly covered in a manner suitable rather to the medical student than for the radiotherapist in training. The general methods of Radiation Therapy are dealt with in a single paragraph.

One looks in vain through the remainder of this book for the anatomico-clinical principles which govern the irradiation therapy of cancer; none are given. When the author deals with radiation techniques, one is faced with a single method of treatment, which appears to be independent of the form of the cancer to be treated. Variation in the time-dose schedule, and the changing factor of the irradiated volume are not discussed, though they are essential to the treatment of malignancy by radiation. The statement, "the number of days chosen for application of the total dose is the most important factor and should always be stated", gives promise of some interest in this subject, but it seems to be dismissed in the next paragraph by "a series of treatments is commonly extended over a period of 28 to 30 days".

Treatment techniques are presented according to a classification based on different body systems, with physical factors being referred to by symbols. This gives the volume an alarming resemblance to a recipe book, particularly with the standard treatment of 28 to 30 days, with a few exceptions.

Treatment portals are in most cases very large, and in some cases one would think unnecessarily so, as in the recommendation for ovarian sterilization with a 15 x 20 cms. field.

Altogether this book appears to be an attempt at simplification of radiotherapy which has unfortunately resulted in over-simplification.

R.L.

TOTAL BODY RADIATION AND DOSE TO THE GONADS FROM THE THERAPEUTIC USE OF IODINE 131: A SURVEY OF 20 CASES*

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1. INTRODUCTION

This paper considers the radiation hazard to a series of 20 patients (February 17, 1958 to February 26, 1960) resulting from therapy with I^{131} for carcinoma of the thyroid, hyperthyroidism, ablation of the thyroid gland in angina pectoris and, in one case, from a smaller dose administered prior to total-body scanning to detect metastases. The method used is the one described in our previous paper on this subject[3]. The study of one hyperthyroid patient (Mrs. C. H.) treated with 8 mc. of I^{131} is used as an illustration of the method. As in reference 3 we consider separately the two hazards, total body radiation and dose to the gonads. In both cases we estimate the dose in rads with no attempt to estimate the somatic or genetic damage resulting.

2. TOTAL BODY RADIATION

We make the following simplifying assumptions:

1. Excretion of I^{131} is entirely through the kidneys.
2. I^{131} not yet excreted or decayed and not contained in the thyroid is uniformly distributed throughout the body.**
3. The body is homogeneous and of unit density.**
4. The beta radiation from I^{131} content is considered to be entirely absorbed within the body since the maximum range in tissue is 2 mm.

The radiation received per unit mass is, in fact, not constant throughout the body. Thus, the phrase "total body radiation" is used somewhat loosely in the sense that it represents an average value. Moreover, since the high dose received by the thyroid (if present) is, in each case, the desired result of the treatment, we exclude the thyroid from our estimate of the average.

There are three contributions to total body radiation:

(a) beta and (b) gamma radiation from I^{131} distributed throughout the extra-thyroidal tissue

(c) gamma radiation from I^{131} in the thyroid.

To evaluate these contributions the method is that described in reference 3. The relevant curves in the case of Mrs. C. H. are shown in Figure 1. Curve A shows the total-body content of I^{131}, namely, the original dose corrected for decay and urinary excretion as a function of time. Curve B is the thyroid content. The two curves join before the end of the first day which means that substantially all of the I^{131} is very quickly contained in the thyroid gland. This is demonstrated also by Curve B which shows a very small I^{131} blood content by the end of the first day.

(a) *The beta contribution to total body radiation.*

$$\bar{D}_\beta = \frac{2.1\,\bar{E}_\beta}{M}\int_0^t I\,dt \quad \text{rads} \qquad (4, p. 824)$$

where $\bar{D}_\beta$ = average integral beta dose in rads to time t

$\bar{E}_\beta$ = average beta-particle energy in mev.

M = body mass in kg.

I = total I^{131} body content in mc exclusive of the thyroid.

The value of the integral is, of course, the area between the two curves in Figure 1.

(b) *The gamma contribution to total body radiation from I^{131} in extra-thyroidal tissue.*

$$\bar{R}_\gamma = c\rho\Gamma\bar{g} \qquad (4, p. 857)$$

where $\bar{R}_\gamma$ = average gamma dose rate from I^{131} distributed uniformly throughout the body.

* *Supported by Alberta Division, Canadian Cancer Society.*

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***It is known that the 'iodine space' of a 70 kg. subject is about 20 litres. The distribution of a dissolved substance cannot be specified, so that the assumptions of uniform distribution and unit density are the only ones we are able to make at the present stage.*

c = I^{131} concentration in mc/gm.
ρ = tissue density.
Γ = point-source gamma dose rate constant in air.
$\bar{g}$ = average geometrical factor determined by subject height and weight (4, p. 858)

Then the average dose to extra-thyroidal tissue is given by

$$\bar{D}_\gamma = \frac{\rho\Gamma\bar{g}}{1000M}\int_0^t I\,dt \quad \text{roentgens}$$

The value of the integral is again the area between the two curves in Figure 1.

(c) *The gamma contribution from I^{131} in the thyroid.*

The easiest way to obtain this contribution is to evaluate the dose that would be delivered to the thyroid by the I^{131} in the thyroid if it were distributed throughout the extra-thyroidal space. This is the desired result by virtue of the reciprocal theorem. (4, p. 718)

$$R_{\gamma P} = c\rho\Gamma g_P$$

where $R_{\gamma P}$ = the dose rate at the thyroid
c = I^{131} concentration in mc/gm that the thyroid content would produce if distributed throughout the extra-thyroidal space.
g_P = a geometrical factor for the thyroid relative to the rest of the body (4, p. 856)

The rest of the analysis is a simple modification of that in (b) above.

In the case of Mrs. C. H. a therapy dose of 8 mc. of I^{131} was administered and the results were the following:

beta	0.2	rad
extra-thyroidal gamma	0.1	roentgen
thyroidal gamma	6.3	roentgens
total body radiation	6.6	rads
or	0.83	rad/mc

We have made no distinction between roentgens and rads because of the approximations already made.

RESULTS

The results for total body radiation are shown in Table II.

3. RADIATION TO THE GONADS

There are five sources of radiation to the gonads:

(a) beta radiation from blood flowing through the gonads and gamma radiation from (b) the thyroid, (c) the extra-thyroidal tissue, (d) the bladder and (e) the colon.

Of the 20 cases here presented, two are males. If we imagine two subjects, one male, the other female, which are otherwise identical, it is likely that the gonadal dose would be smaller in the case of the male because of smaller doses from sources (b), (d) and (e). However, to make this distinction would be a refinement which the accuracy of our method would scarcely justify. Thus we have treated all subjects as females.

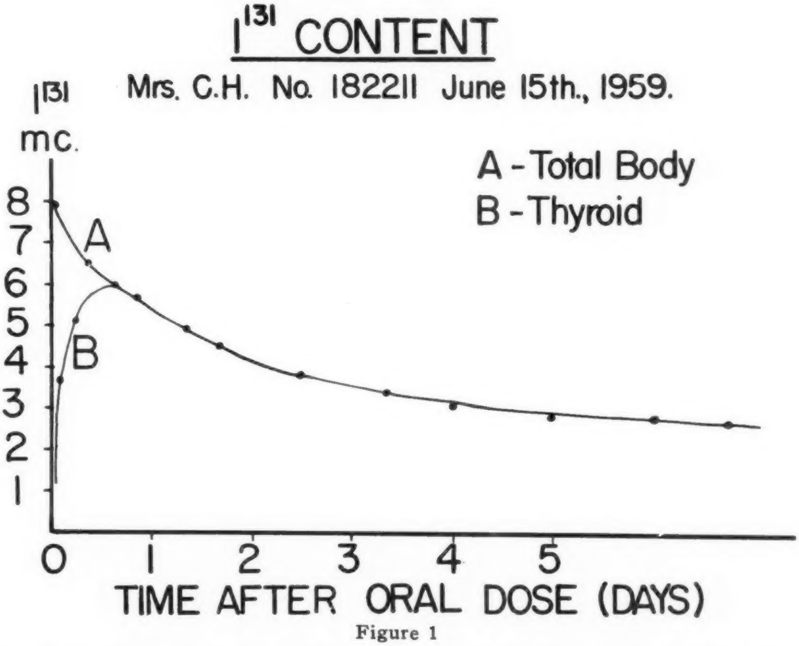

Figure 1

(a) *Beta radiation from blood flowing through the gonads.*

As described in reference 3 we require the I^{131} concentration in whole blood as a function of time. Figure 2 shows the resulting curve in the case of Mrs. C. H.

The method is that used for assessing the beta contribution to total body radiation above with one modification. As in reference 3 we have applied a fraction of one third to the beta energy originating in unit volume of blood as the likely fraction absorbed in the gonads.*

(b) *Gamma radiation from the thyroid.*

The procedure is that described[3] using the lower curve in Figure 1. There is considerable uncertainty about the exact position of the ovaries in each case and the estimated dose is quite sensitive to the value chosen for the thyroid-ovary distance. For example, at an assumed distance of 50 cm. an uncertainty of 1 cm. introduces an uncertainty of 7% in the assessment of gamma dose from the thyroid, and there is no way of improving the accuracy. In all cases we have taken the ovaries to be at the level of the symphysis pubis. The distance in the case of Mrs. C. H. was 46 cm.

(c) *Gamma radiation from extra-thyroidal tissue.*

$R_{\gamma P} = c\rho\Gamma g_P$ (4, p. 853)

where $R_{\gamma P}$ = the dose rate at a point P (the ovaries)

g_P = a geometrical factor for the ovaries taken to be 175 cm. (4, p. 856)

and the other symbols have the meanings already defined.

Then the dose to the ovaries is given by

$$D_{\gamma P} = \frac{\rho\Gamma g_P}{1000\ M} \int_0^t I\,dt \quad \text{roentgens}$$

where the value of the integral is given by the area between the two curves in Figure 1.

(d) *Gamma radiation from the bladder.*

The estimate of this contribution was made as described in (3).

We may write

$R_{\gamma P} = c\rho\Gamma\ 4\pi R\ F(d/R)$ (4, p. 853)

where R = radius of the bladder, assumed to be a sphere

d = distance from bladder centre to the external point of irradiation (the ovaries)

F(d/R) = a function whose value depends on the value of (d/R) (4, p. 854)

Then the dose to the ovaries during an eight-hour period may be written

$$D_{\gamma P} = \rho\Gamma\ 4\pi R\ F(d/R) \frac{I}{V} \times 4 \quad \text{roentgens}$$

where I = total I^{131} content in the eight-hour urine sample

V = volume of urine collected in the eight hours.

The factor 4 appears because, as explained[3], in order to make some estimate we have supposed that the bladder was empty during the first half of each eight-hour period and full during the second half with the volume being that of the eight-hour collection.

It is usually sufficient to make urine collections during the first five days following administration. From the dose received during this period it is possible to extrapolate, where necessary, with sufficient accuracy to the total dose. Table I shows the values, in the case of Mrs. C. H., of the successive eight-hour contributions to gonadal dose from the bladder.*

TABLE I

Time Interval Following Oral Administration of 8mc. I^{131} (hours)	Gamma Dose to the Ovaries from I^{131} Bladder content (mr)
0 — 8	204
8 — 16	120
16 — 24	55
24 — 32	27
32 — 40	19
40 — 48	11
48 — 72	3
72 — 96	2
96 — 120	1
Total	442 mr

(e) *Gamma radiation from the colon.*

The method is that described in reference 3 and in (d) above for gamma radiation from the bladder.

RESULTS

The results for Mrs. C. H. were:

(a) beta radiation from blood	0.70
gamma radiation from	
(b) the thyroid	0.30
(c) extra-thyroidal tissue	0.19
(d) the bladder	0.44
(e) the colon	0.10
total radiation to the ovaries	1.73 rads
or	0.27 rad/mc.

* *We are investigating the validity of this approximation by comparison of ovary and blood I^{131} concentration following a tracer dose given prior to oophorectomy.*

* *An alternative approach is that recently published by Comas and Brucer[2].*

Again we have treated rads and roentgens as equivalent units.

The results for gonad dose are shown in Table III.

4. DISCUSSION

(a) *Total body radiation.*

The mean value of total body radiation for all 20 cases is 0.51 rad/mc. This is not a particularly significant figure since the individual values vary from 0.10 to 1 87 rad/mc. The various groups in Table II have been arranged so that there is a general increase in total body radiation from the top down and the order is roughly what one would expect. At least the two extremes are reasonable: the lowest value for thyroid cancer with no active thyroid and no active metastases, and the highest for thyroid cancer with some active thyroid and active metastases. For cancer patients the concern to keep the total body radiation minimal is not so great as with non-cancer patients. The mean for this latter group is 0.67 rad/mc. One patient in this group (Miss M. G.) has what we believe to be an abnormally high value (1.87 rad/mc.) because of her low body mass (33.4 kg.). The mean for the non-cancer group, without this high value, is 0.53 rad/mc.

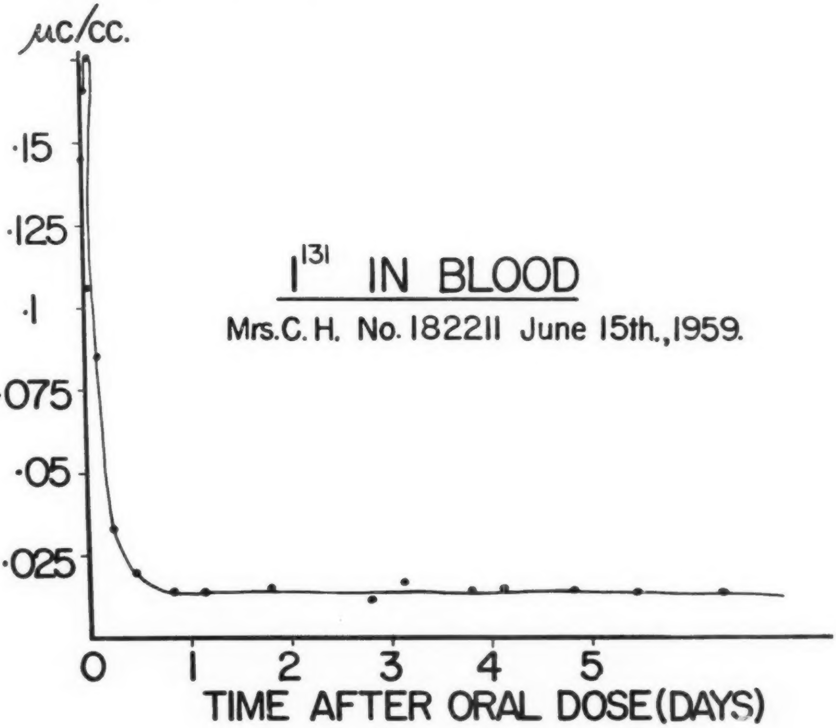

Figure 2

(b) *Dose to the gonads*

The mean gonad dose for the 20 cases is 0.45 rad/mc, a value which fortuitously agrees with that estimated by Johns and Taylor[6]. The spread in the values is roughly a factor of three either way from 0.13 to 1.17 rad/mc. The chief concern regarding gonad dose is likely to be with the non-cancer group. The mean for this group is 0.42 rad/mc., not significantly different from the over-all mean.

The last column in Table III shows, as a percentage, the fraction of the total gonad dose which is contributed by gamma radiation from the bladder. In 11 cases, more than 50% of the total comes from this source and in four of the remaining nine cases the bladder was still the greatest single contributor. The importance of the bladder contribution suggests that it would be worth while to make more refined assessments than were made in our work. For example, each excretion might be dealt with as a separate sample, rather than arbitrarily dividing each day into three eight-hour periods. On the other hand, the position of the ovaries relative to the bladder is not known at all accurately in each case and this uncertainty greatly dominates that introduced by our simplified method.

In view of the dominant role played by the bladder in gonad dose it would perhaps be useful to increase the fluid intake of treated patients thus encouraging frequent micturition. While this would be unlikely to speed the excretion of I^{131} it would reduce the resident time in the bladder.

(c) *Comparison with other work.*

Table IV shows, in chronological order, recent results of other workers in comparison with those of the present investigation.

5. SUMMARY

Results are given for assessments of total body radiation and dose to the gonads resulting from I^{131} therapy for 20 cases, thyroid cancer(10), hyperthyroidism(7) and ablation of the thyroid for angina pectoris(3). The method depends upon assessment of I^{131} content in urine and fecal excretion over a five-day period, and in thyroid and whole blood for a minimum of five days and up to 28 days where possible. Mean values are, for total

TABLE II

Total Body Radiation from Oral Administration of I^{131}

Type of Case	Subject			Contributions to Total Body Radiation rad/mc			Total Body Radiation rad/mc
	Identity	Mass (kg)	Dose (mc)	Beta	Gamma Extra Thyroidal Space	Gamma Thyroid	
I							
Ca Thyroid	Mr. GPS	63.6	100	0.053	0.035	—	0.088
No Thyroid	Mrs. MB	53.6	1	0.060	0.040	—	0.10
No known Metastases							
II							
Ca Thyroid	Mrs. MB	53.6	40	0.105	0.068	0.055	0.23
Some Thyroid	Mrs. VW	86.8	30	0.066	0.050	0.009	0.13
No known Metastases	Miss HP	76.8	25	0.104	0.072	0.080	0.26
	Mrs. AH	91.4	69	0.061	0.048	0.026	0.14
	Mrs. JW	53.6	50	0.060	0.039	0.200	0.30
III							
Euthyroid	Mr. JMG	87.2	35	0.092	0.066	0.140	0.30
	Mrs. LK	81.8	33	0.097	0.073	0.109	0.28
	Mrs. EK	66.4	30	0.098	0.067	0.100	0.27
IV							
Hyperthyroid	Mrs. AR	62.3	40	0.153	0.103	0.310	0.57
Nodular	Mrs. JS	60.9	16	0.006	0.046	0.682	0.73
	Mrs. JS	60.9	20	0.010	0.006	0.400	0.41
V							
Ca Thyroid	Mrs. AF	59.0	100	0.410	0.297	—	0.71
No Thyroid	Mrs. AH	91.4	125	0.217	0.224	—	0.44
Active Metastases							
VI							
Hyperthyroid	Miss MG	33.4	9	0.600	0.333	0.933	1.87
Diffuse	Mrs. CH	54.5	8	0.025	0.015	0.788	0.83
	Sister MC	50.0	8	0.056	0.038	0.445	0.54
	Miss EW	54.0	5	0.064	0.046	0.742	0.85
VII							
Ca Thyroid	Mrs. AF	59.0	100	0.653	0.439	0.049	1.14
Some Thyroid							
Active Metastases						Mean	0.51
				Mean of non-ca groups (III, IV, VI)			0.67

TABLE III

Gonad Dose from Oral Administration of I^{131}

(The order of cases is the same as that in Table II)

Type of case	Contributions to Gonad Dose rad/mc					Total Gonad Dose rad/mc	Bladder ÷ Total %
	Blood	Thyroid	Bladder	Colon	Extra-thyroidal tissue		
I	0.053	—	0.20	0	0.043	0.30	67
	0.040	—	0.20	0	0.050	0.29	69
II	0.044	0.003	0.19	0.003	0.100	0.34	56
	0.069	0.001	0.28	0.010	0.063	0.42	67
	0.058	0.012	0.19	0.008	0.100	0.37	51
	0.046	0.003	0.20	0.006	0.058	0.31	65
	0.174	0.011	0.18	0.004	0.057	0.43	42
III	0.048	0.010	0.13	0.011	0.074	0.27	48
	0.084	0.006	0.23	0.009	0.094	0.42	55
	0.067	0.011	0.22	0	0.093	0.39	56
IV	0.063	0.043	0.16	0.010	0.147	0.42	38
	0.052	0.050	0.08	0.013	0.007	0.20	40
	0.016	0.027	0.07	0.010	0.009	0.13	54
V	0.097	—	0.18	0.008	0.446	0.73	25
	0.076	—	0.20	0.001	0.208	0.49	41
VI	0.341	0.067	0.056	0.022	0.578	1.06	5.3
	0.088	0.038	0.055	0.013	0.024	0.22	25
	0.179	0.020	0.42	0.006	0.054	0.68	62
	0.077	0.042	0.25	0.010	0.062	0.44	57
VII	0.350	0.002	0.18	0.012	0.624	1.17	15
		Mean	0.18		Mean	0.45	
			Mean of non-ca groups (III, IV, VI)			0.42	

TABLE IV

Source	Method	Case	Dose (mc)	Total Body Radiation	Gonad Dose
(8)	autopsies	8 ca Thyroid 1 goitre	2–250		0.65 er/mc to ovaries 0.33 er/mc to testes
(7)	blood levels in 20 patients	ca thyroid	100	1.0 r/mc range 0.3–3.0	
(1)	phantom bladders	hyperthyroid	10		0.16 rad/mc
(5)	not stated	toxic goitre	7	0.57 rad/mc	1.43 rad/mc
(6)	theoretical	hyperthyroid	5 (average)		0.45 rad/mc
(2)	phantom pelvis and urine collection	hyper (4) hypo (2)	1–6.5 100, 102		2.4 rads/mc 1.96, 2.82 rads/mc
present investigation	thyroid uptake, urine collection, blood level	hyper and euthyroid, ca thyroid	1–125	0.51 rad/mc range 0.10-1.87	0.45 rad/mc range 0.13-1.17

body radiation, 0.51 rad/mc, (range 0.10 - 1.87 rad/mc.) and, for gonad dose, 0.45 rad mc. (range 0.13 - 1.17 rad/mc.).

The contribution to gonad dose due to gamma radiation from the bladder was greater than 50% of the total in 11 cases and was greater than any other single source in four of the remaining nine. It is suggested, in order to minimise gonad dose, that high fluid intake following I^{131} administration be used to induce frequent micturition thus reducing the resident time in the bladder of excreted I^{131}.

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MILKMAN'S SYNDROME — Five Cases of Severe Osteomalacia Following Gastric Surgery.

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The post-gastrectomy malfunction syndromes are well known, and the consequent intestinal malabsorption is not frequently severe. Marked osteomalacia following this type of malnutrition is rarely reported in the literature, so we propose to add five cases found between the years 1955 and 1959.

Milkman's Syndrome comprises osteomalacia with spontaneous and symmetric fractures of bone, showing abortive attempts at repair by non-ossified callus. These are so-called "Transformation zones" in which well organized osteoid tissue can be demonstrated histologically. This osteoid fails to become impregnated with calcium salts; the general calcium content of the bone is also markedly diminished[6].

It is known experimentally that after gastrectomy adolescent dogs will consistently show a severe degree of osteomalacia, whereas the bones of adult dogs are not usually similarly affected[5]. On this basis, one may assume that if the post-gastrectomy Milkman's Sydrome in man is uncommon, it is partly because gastric surgery has usually been reserved for patients past the growth period.

TABLE 1

Sex	Age at Initial Gastric Surgery	Interval Gastrectomy to Osteomalacia Symptoms	Interval Gastrectomy to discovery of Milkman	Year
F.	29	1	6	1955
F.	23	?	15	1956
M.	32	4	4	1957
F.	33	2	2	1957
F.	34	3	2	1959

Table 1 — Age, Sex and Gastrectomy to Osteomalacia Interval Distribution.

Although sub-total gastric resection is now considered a safe and effective surgical procedure, it is fraught with the danger of subsequent disturbances of intestinal function. It has been observed that these disturbances may occur even after the simplest procedures when the method of gastric evacuation is altered[3]. The frequency and severity of the disturbance is unpredictable, but one can assume from the experiments in dogs that the younger the patient at the time of gastrectomy, the greater the chance for post-operative symptoms. Our patients underwent initial gastric surgery at an average age of 30 years (Table I), and in all cases the operative procedures were done for the treatment of peptic ulcer. The interval between surgery and the onset of symptoms attributable to bone disease was approximately 2 to 4 years, with the patients showing varying degrees of dumping syndrome during this interval. Only one of these patients had the initial operation in our institution.

The dumping syndrome, which appears to be the cause of the malnutrition, occurs in 5 to 10% of post-gastrectomy patients, and is more prone to occur after a meal of high osmolarity[1,4]. In some instances, symptoms appear in 10 minutes and last up to 40 minutes; there may be associated disturbances in blood plasma volume and in serum potassium levels. In other cases, an interval of about 3 hours precedes the onset of symptoms; this type of late post-prandial disturbance usually coincides with low blood glucose levels[4]. In either group of symptoms, patients complain of faintness, diaphoresis, pallor, dizziness, epigastric emptiness, nausea, vomiting and diarrhoea. Objective findings include tachycardia, increased volume of small bowel content, fall in blood plasma volume, low blood potassium levels, altered electrocardiographic patterns, elevation of uric acid excretion, decreased circulating eosinophils, hyperglycemia, lowered cardiac output, and occasional elevation of blood pressure.

In view of the great complexity of physiological changes involved, it would appear logical to relate these findings to multiple causes. Yet, a common theory is based on the osmotic attraction of interstitial fluids

into the jejunum by a small bowel bolus of high osmolarity; a state of mild shock is thought to follow, caused by lowered blood plasma volume.

Recently, however, it has been shown that biological disturbances, osmotic imbalance and changes in blood plasma levels of the same order and character may also occur in completely asymptomatic patients[3,4]. According to Morris[3], the only distinctive feature between symptomatic and asymptomatic cases is the existence of an increased renal blood flow in those with symptoms. This increase in renal flow would suggest the action of an adrenalin-like substance as the cause for the poor tolerance to the disturbance in plasma volume produced by the jejunal hyperosmolarity.

Thus, it seems unlikely that a single radiologic test would efficiently predict the extent and severity of malabsorption in a patient with dumping syndrome, or determine whether the dumping syndrome is symptom producing or not, if we exclude from discussion the question of small gastric stoma.

Case Presentations:

CASE I:

This 35 year-old female had had a gastrectomy 2 years previously for acute bleeding ulcers of the stomach, and when seen by us she had few complaints upon ingestion of food, although since operation she had tended to eat only small meals. Radiographically she showed the picture of advanced osteomalacia with a number of pseudo fractures (Figure 1.) The hand, leg and foot show thinning of cortical bone with spongiosa-like cortices, diffuse decalcification and preterminal transverse striation (Figure 2). Though changes are most marked in the lower extremity, the hand more nearly represents the true situation, as any such debilitated patient will show some degree of disuse osteoporosis in the legs[6].

CASE II:

This 38 year-old female had a gastrectomy at age 23. Dumping syndrome was so severe following the operation that further procedures were done including gastrectomy, vagotomy, jejuno-jejunostomy and caecostomy. She still cannot retain any large amount of fluid or high glucose food. The films (Figure 3) show only 2 consolidated fractures, unrelated to trauma.

COMMENT: These two cases illustrate that no clear connection can be shown between the severity of dumping syndrome and the degree of osteomalacia.

Figure 1 — Pseudo fractures of ribs in a patient with few digestive complaints after gastrectomy. CASE I.

Figure 2 — Comparison of the mineral content of the bone, in the hand, the leg and the foot. CASE I.

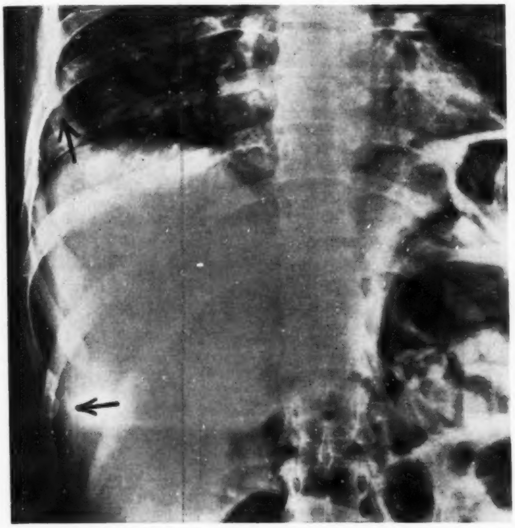

Figure 3 — Two healed rib fractures in a patient who has complained of severe post-gastrectomy dumping symptoms since her operation 15 years ago. CASE II.

CASE III:

This 35 year-old female patient had a gastroenterostomy done at age 29. Two years later, because of dumping symptoms, a sub-total gastrectomy was performed and then, within a year, the patient noticed the onset of sciatic and pelvic pain. When first seen by us, her bone pain had progressed to involve the thoracic cage and upper and lower portions of her back. Though partially incapacitated, she still performed her duties in a religious order. For some years she had been feeding almost exclusively on melba toast, as any prepared meal caused distressing epigastric discomfort. Figure 4 shows her late response to glucose absorption, with the blood level at 35 mgms % in 2½ hours, corresponding with maximum symptoms. Pathologic rib fractures were demonstrated (Figure 5), and fractures in pubis and hips were also shown (Figure 6). Healing of the fractures and improvement of the osteomalacia following treatment was demonstrable in 8 weeks (Figure 7).

CASE IV:

A 35 year-old male, who had a gastrectomy in 1952, 5 years before admission here. He described his symptoms following ingestion of food as early diaphoresis, heat flush, dizziness and occipital headaches, followed by a late sensation of great abdominal fullness and later diarrhoea with fatty stools. Conversion of Billroth II to Billroth I anastomosis and thoracic vagotomy have failed to improve his symptoms. The type of rib fractures found in this patient are shown in Figure 8.

Simultaneous determination of blood plasma volume, blood glucose and potassium levels were made, upon the ingestion of 2 ounces of barium in 150 ccs. of 50% glucose solution[1]. Films were also

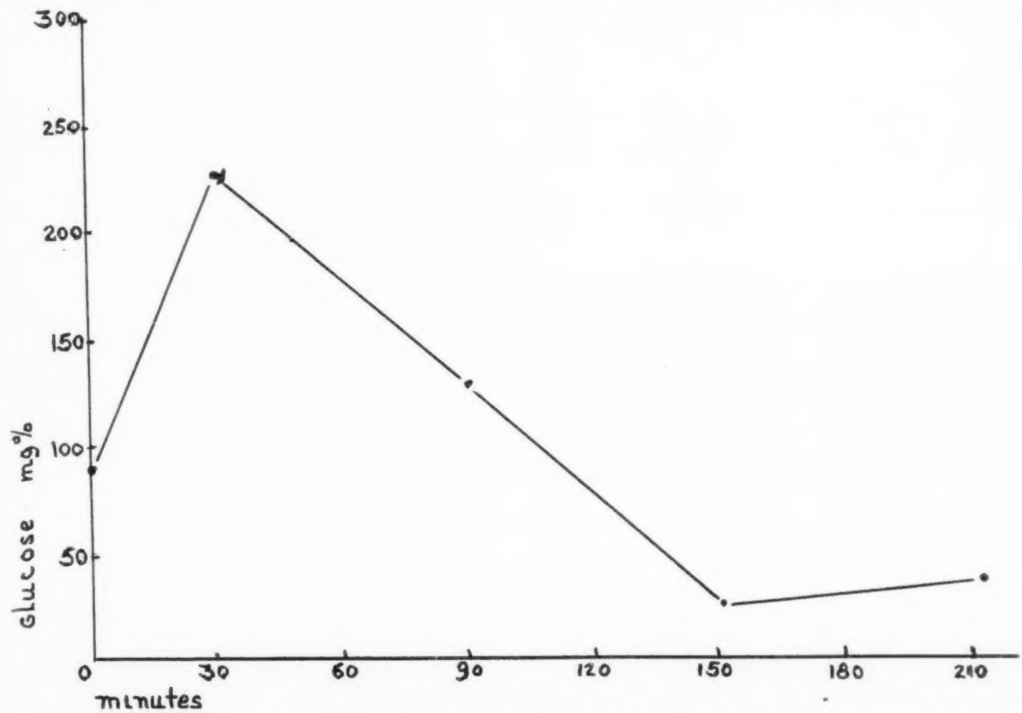

Figure 4 — Late response to glucose absorption test, showing a 35 mgms. % level at 2½ hours. CASE III.

taken at the time of each biochemical determination. Glucose levels did not show any abnormality, but serum potassium showed an early drop corresponding to the onset of symptoms (Figure 9). A plasma volume fall of nearly 900ccs., a 25% decrease, coincided with the abdominal fullness described. The plasma curve was obtained with Evans Blue, the inverse of optical densities, not corrected for urinary excretion, being used. The normal volume thus must be read as an ascending line on the graph. Simultaneously dilatation of the jejunum and edema of mucosal folds is shown on the 15 minute film (Figure 10) and dilution, fragmentation and moulage on later films (Figure 11).

By comparison, a series taken from conventional examinations of the same patient (Figure 12) shows that osmotic phenomena could be better elicited with the special studies.

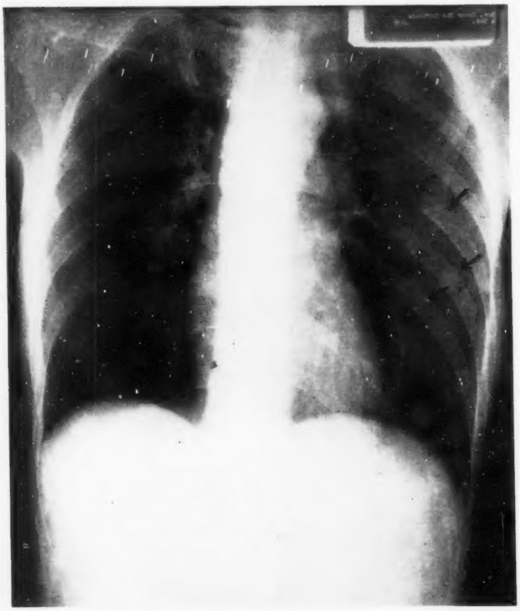

Figure 5 — Pathological rib fractures in a 35 year-old patient, 6 years after gastrectomy. CASE III.

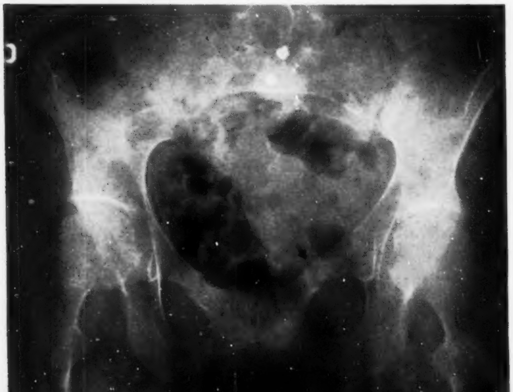

Figure 6 — Pathological fractures in pubis and right hip, CASE III.

Figure 7 — Healing phase of fractures, after 8 weeks. CASE III.

Figure 8 — Fractures of the ribs, in a 36 year-old male, 4 Years after gastrectomy. CASE IV.

CASE V:

Female, age 37. Three years previously, at age 34, she had had a gastrectomy. She presented with complaints of lumbar, thoracic and pelvic pain of one year's duration. Blood glucose absorption and readjustment were normal (Figure 13). However blood plasma and potassium disturbances were demonstrated early, corresponding to onset of symptoms. The plasma volume showed a 25% relative drop in 15 minutes, a condition usually associated with clinical shock, but well tolerated by this patient.

The 15-minute film (Figure 14) of the conventional examination when compared with that of a barium glucose examination (Figure 15), is shown. The same comparison is made at 1 hour intervals (Figures 16 & 17). Distension, edema, dilution and the deficiency pattern are better shown with the latter technique. A pelvic ramus fracture was demonstrated (Figure 18), with ossification after 6 weeks of medical management (Figure 19).

Summary:

Five cases of osteomalacia following gastric surgery are presented. Their median age was 30 years, and symptoms of the dumping syndrome occurred in all patients, and all showed secondary malabsorption and malnutrition. This report emphasizes the greater likelihood of complications of this type following a gastrectomy in the young patient, and the need for caution in the evaluation and selection of young ulcer patients for gastrectomy.

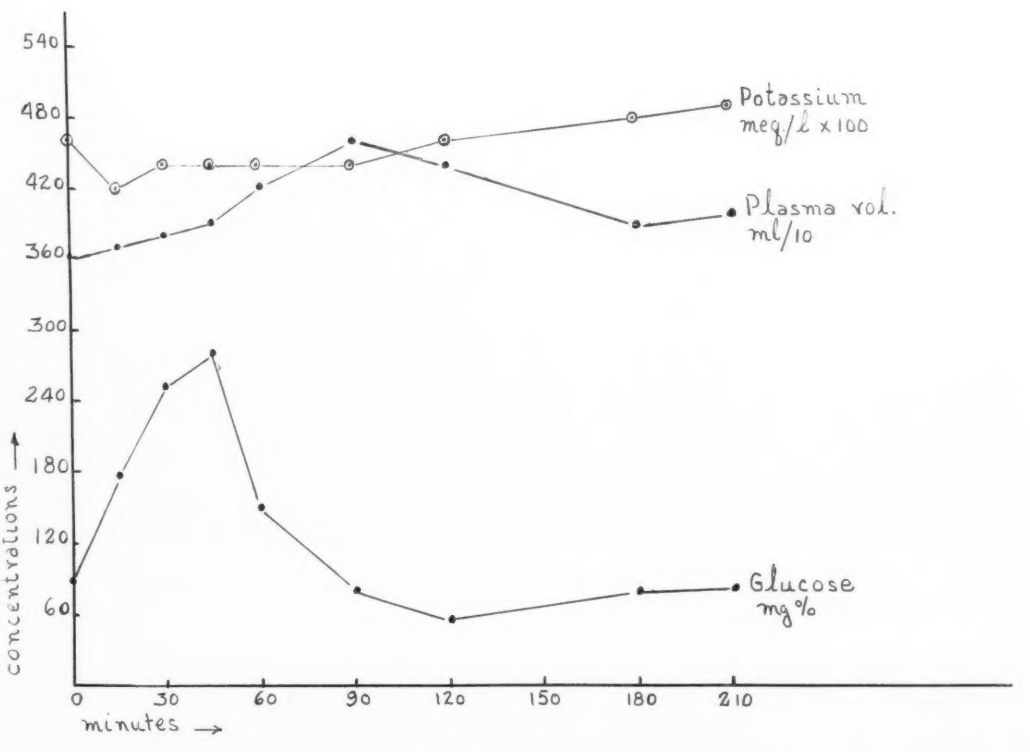

Figure 9 — Variations in blood plasma volume, blood potassium and glucose levels, after oral administration of 2 ounces barium in 150 ccs. of 50% glucose solution, in a patient with post-gastrectomy dumping syndrome. CASE IV.

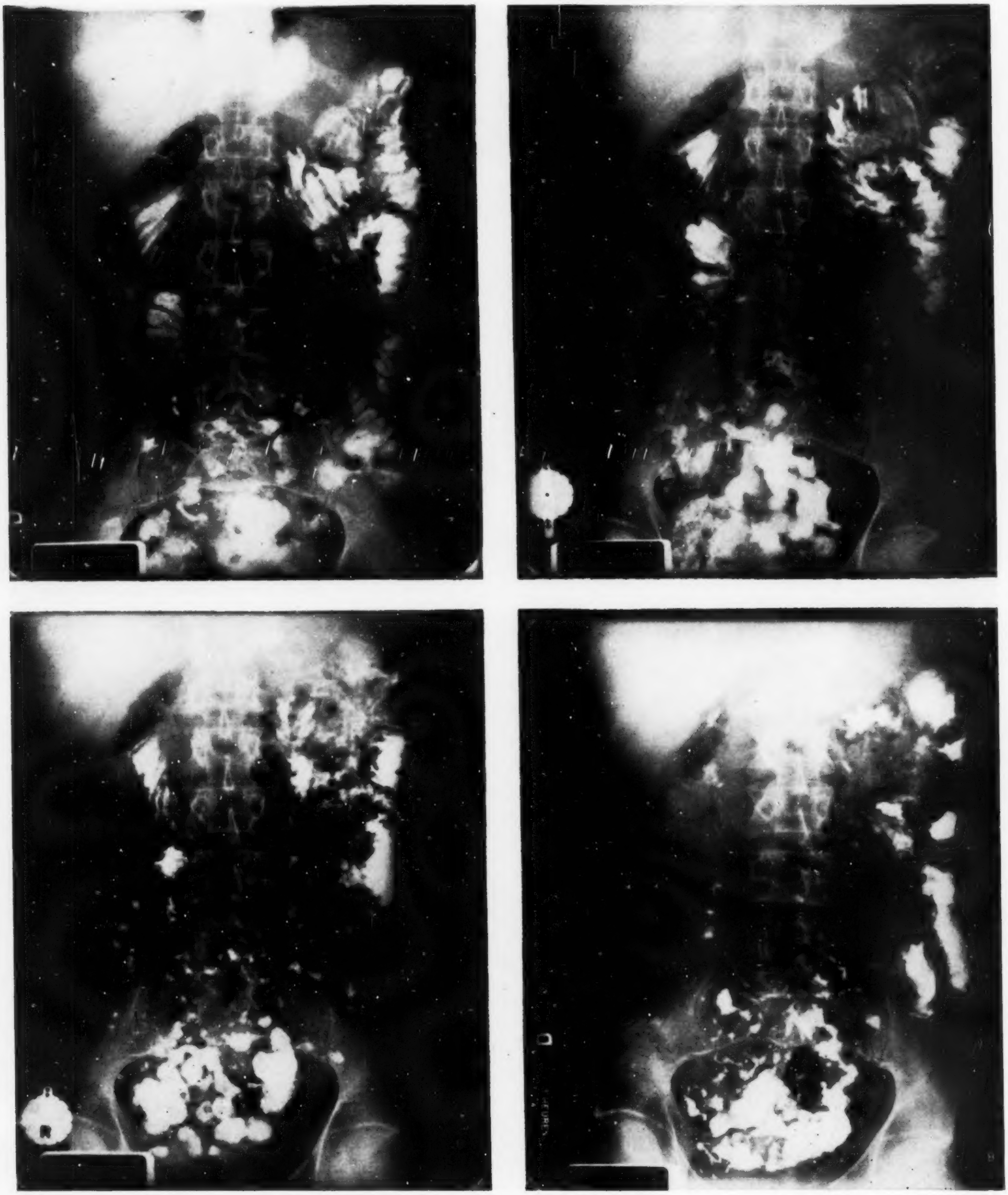

Figure 10 — Films taken 15, 30, 45 and 60 minutes after oral administration of 2 ounces barium in 150 ccs. of 50% glucose solution. CASE IV.

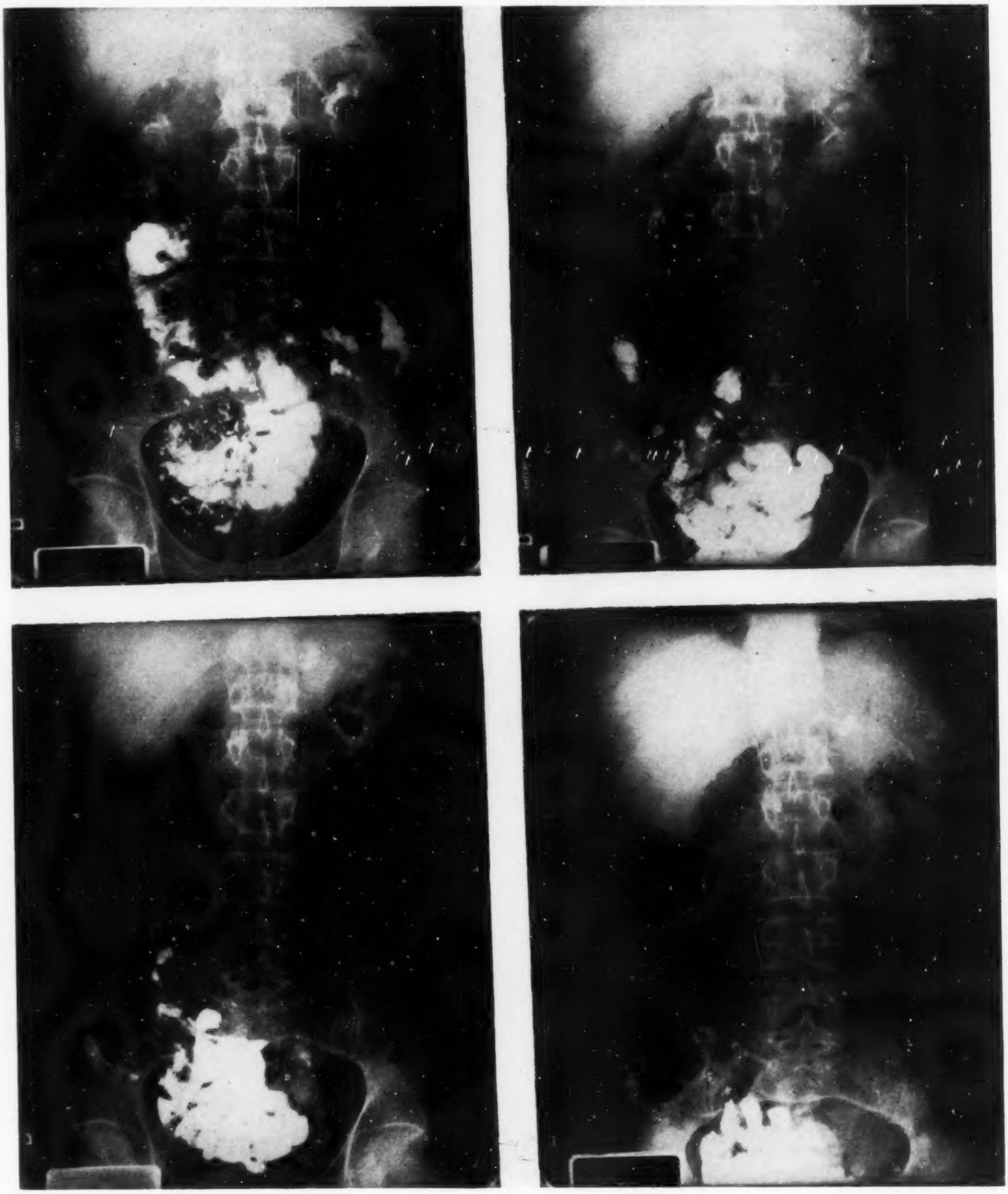

Figure 11 — Films taken 90, 120, 150 and 180 minutes after administration of the barium-glucose mixture. CASE IV.

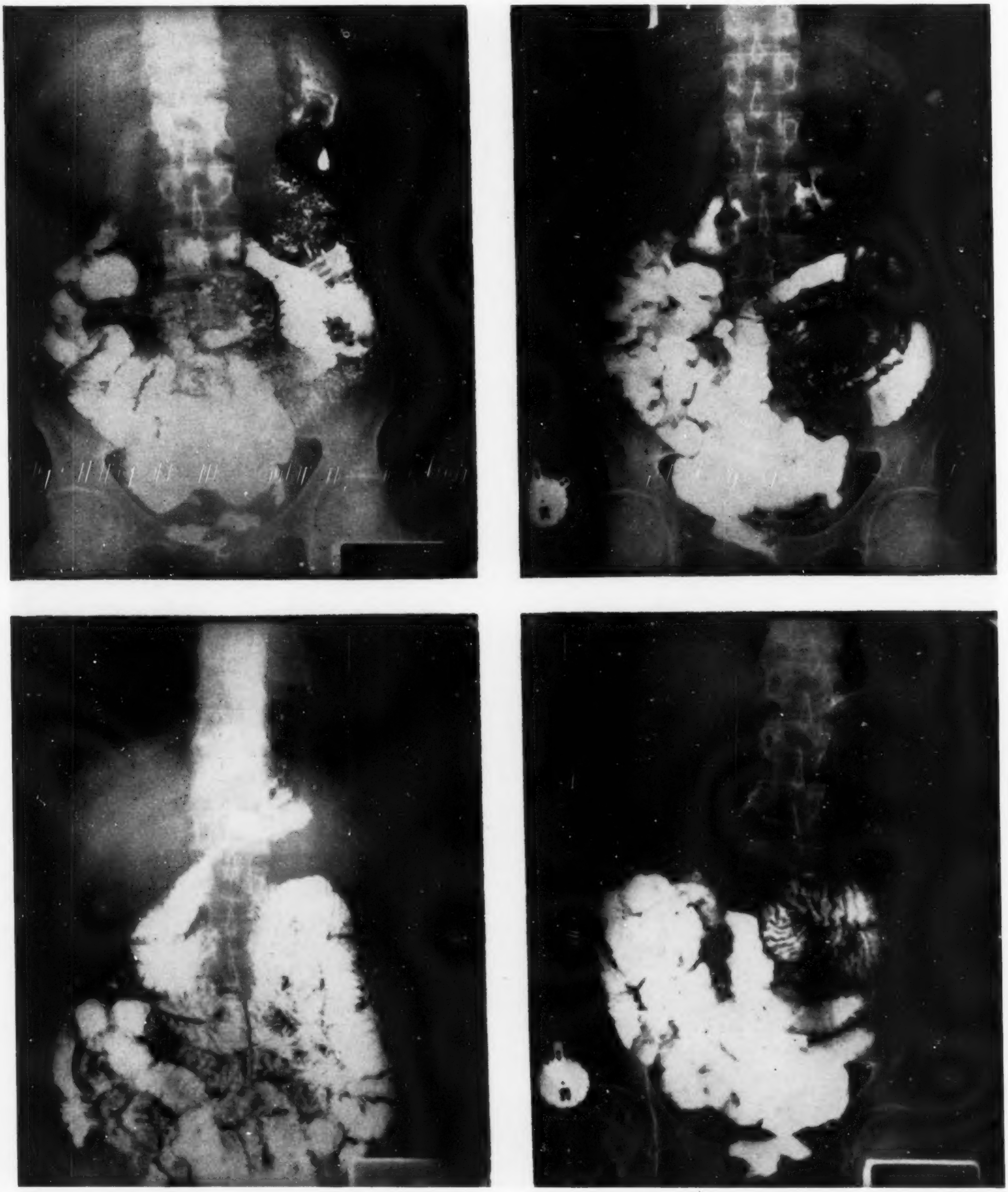

Figure 12 — Small bowel examinations using a barium suspension in water, same patient, CASE IV. Comparison with figures 10 and 11 shows that osmotic phenomena are better demonstrated in the previous study.

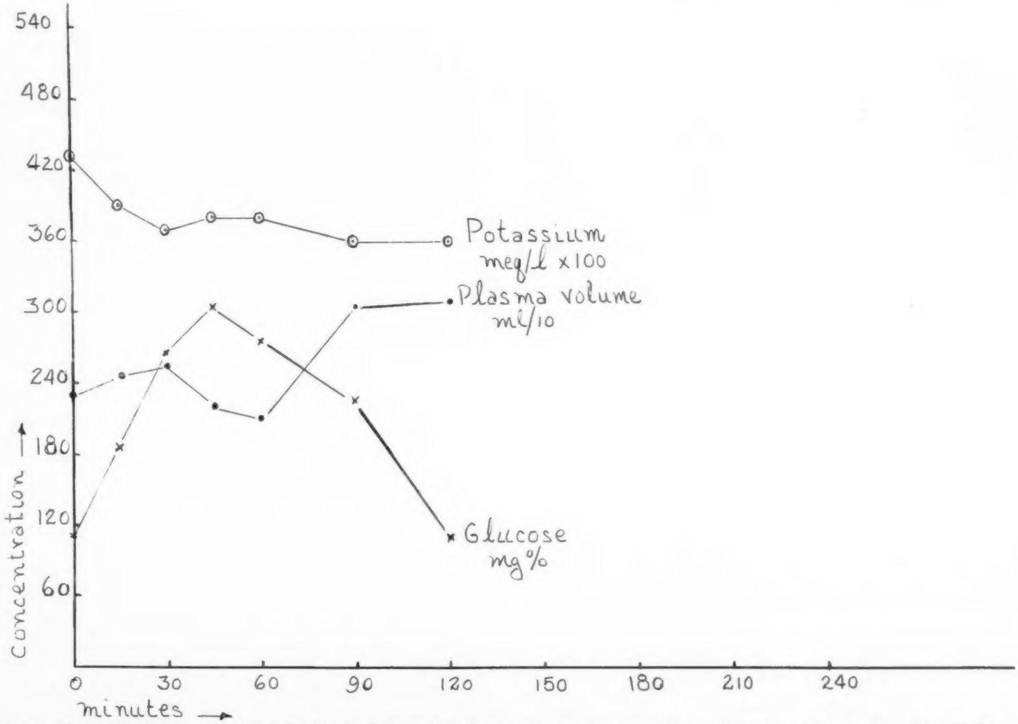

Figure 13 — Variations of biological determinations after the test described in figure 9; CASE V.

Figure 14 — 15-minute film of a conventional examination of the small bowel. CASE V.

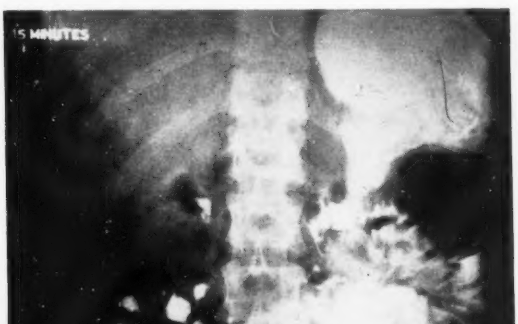

Figure 15 — 15-minute film of the special barium-glucose examination, showing initial dilatation of the jejunum. CASE V.

Figure 16. — One-hour film of small bowel study with barium in water. CASE V.

Figure 17 — One-hour film of the barium-glucose exploration, to show the effect of dilution and distension in the small bowel. CASE V.

Figure 18 — Fracture of a pelvic ramus, CASE V.

Figure 19 — Ossification of the callus at the fracture site six weeks after discovery.

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FACTORS DETERMINING QUALITY IN A RADIOGRAPH

with a Discussion of Film Faults and Artefacts

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PART I

There are so many factors determining film quality that it would be unusual to find a radiograph which could not be improved. The discriminating radiologist is alert to the dangers of interpreting unsatisfactory films and constantly strives to improve his technical work to eliminate blemishes and other faults.

It is difficult to define what is meant by quality in a radiograph. There are minor differences of opinion among radiologists in the choice of density and contrast, but there is universal agreement on the importance of good detail and freedom from artefacts. Every radiologist can recall instances where inferior quality has lead to embarrassing misinterpretation of films. With this in mind a discussion of the factors making up quality and of those contributing to artefacts may be of assistance to the beginner in radiology.

TABLE I

FACTORS DETERMINING QUALITY IN A RADIOGRAPH
with a Discussion of Film Faults and Artefacts.

- I. Resolution
- II. Opacity
  - A. Movement
  - B. Screens
  - C. Focal Spot Size
  - D. Distance
  - E. Exposure
  - F. Grain & Graininess
  - G. Parallax
- III. Sensitivity
- IV. Contrast
- V. Gradation
  - A. KVP Mas Ratio
  - B. Filtration
  - C. Total Exposure
  - D. Development
  - E. Screens
  - F. Fog
  - G. Viewing Conditions
- VI. Latitude
- VII. Physical Qualities
  - A. Surface Texture
  - B. Tone
  - C. Dimensional Stability
  - D. Thickness
  - E. Flexibility
  - F. Size
  - G. Flammability
  - H. Permanency
- VIII. Composition
  - A. Artistic Principles
  - B. Perspective
  - C. Magnification
  - D. Distortion
- IX. Artefacts and Film Faults
  - A. Processing Faults
    1. Static Electricity
    2. Pressure & Kink Marks
    3. Abrasions
    4. Finger Marks
    5. Development Mottling
    6. Gravitational Streaming
    7. Bromide Drag
    8. Film Contact
    9. Fog
    10. Reversal
    11. Reticulation
    12. Opalescence
    13. Inadequate Washing Mottle
    14. Water Marks
  - B. Faults During Exposure
    1. Grid Cut-off
    2. Grid Lines
    3. Off-Center Cone, Tube or Filter
    4. Heel Effect of Target
    5. Multiple Images
    6. Fog
  - C. Inherent Film Faults
  - D. Miscellaneous Artefacts
    1. Screen Blemishes
    2. Overlap Density Paradox
    3. Marker Error
    4. Stereoscopic Depth Falsification
    5. Medical Technical Faults
       a. Opaque Media Spillage
       b. Barium Mixture Faults
       c. Faulty Injection Techniques
       d. Errors of Patient Preparation

The various characteristics found in a radiograph may be classified as follows: I. RESOLUTION II. OPACITY III. SENSITIVITY IV. CONTRAST V. GRADATION VI. LATITUDE VII. PHYSICAL QUALITIES VIII. COMPOSITION IX. ARTEFACTS AND FILM FAULTS. Details of these characteristics will be considered according to the plan shown in Table I.

I. RESOLUTION

Resolution in a radiograph refers to the rendition of minute details. Synonymous terms are sharpness and definition. While in theory one should strive for the utmost detail, there is a practical limit so long as radiographs are viewed with the unaided eye. The limit of usefulness is reached when features are represented by dots or lines no more than 1/10 mm. apart, for this is about the limit of detail resolved by the eye at the conventional minimum viewing distance of 10″. This point is not to be ignored in the choice of equipment and its use. For example, since the unsharpness produced by screens produces a blur of 0.2mm to 0.5mm it may not be helpful to reduce the focal spot size below an amount sufficient to produce this degree of sharpness. The factors producing sharpness are not simply additive; detail is, rather, an expression of the largest single factor.

There are of course instances where more detail is desired than is visible to the unaided eye. One might examine a film with a hand lens magnifying to perhaps 3 diameters, or for micro-radiography magnify 50 diameters. As in conventional photography, there is a limit to useful enlargement beyond which the picture is larger but no more revealing; the enlargement is then termed "empty".

There are seven factors affecting resolution:

A. Movement
B. Screens
C. Focal spot size
D. Distance
E. Exposure
F. Grain and Graininess
G. Parallax

A. Movement

Movement is a common source of trouble in the production of detail. This may be movement of the patient, tube or film. With the patient the usual fault is, of course, muscular movement affecting the skeletal portions, but one must also contend with respiratory motion and vascular pulsations as well as contraction and relaxation of other viscera containing muscle. Immobilization by sandbags, clamps, compression cones and other devices eliminates most of this movement in a co-operative patient who can hold his breath. Occasionally one encounters a patient whose diaphragm continues to move in spite of closure of the mouth and nostrils. Speed of exposure is vital in stopping motion. However, in instances where the shortest possible exposure is longer than the period of movement (e.g. heart motion) one may prolong the exposure with no apparent change in quality. Deliberate lengthening of the exposure while movement is permitted may be useful in blurring detail of parts which hide stationary structures (e.g. lungs hiding the dorsal spine and the lower jaw hiding the cervical spine).

Movement of the tube is not often encountered. One must however realize that the value of a fine focus tube is readily nullified by vibration. A 1.0mm focal spot with an excursion of 0.5mm each way from its resting point becomes in effect a 2.0mm focal spot. Dental X-ray units sometimes sacrifice rigidity to mobility and the resulting increase in effective focal spot size may be excessive.

Movement of the film is seldom seen as a fault. It most often occurs when the film is supported weakly in an upright position as in lateral views of the hip in the operating room and in horizontal views taken on a stretcher. Another cause of movement is a Bucky grid which drags on the surface of a cassette which is too thick for clearance.

B. Screens

Screen quality greatly affects detail. Better detail will be obtained by non-screen technique although at the expense of speed in exposure, contrast and additional radiation to the patient. Three grades of screen are in common use in the diagnostic field: slow or detail, par speed and high speed. Detail here is sacrificed to speed.

Each part of a photographic emulsion when exposed to light acts as a secondary source of illumination for neighbouring parts and thus the image is spread in the emulsion. This is known as film irradiation. The effect is greater with thick emulsions. It is considered here in the discussion of screens for most of the radiographic effect when screens are used is by the action of light rather than directly from X-radiation.

Screen irradiation has a similar effect. Crystals adjacent to those exposed by the true image pick up the fluorescence and soften the image margins.

The blur produced by fast screens is such that it may not be advantageous to use the fine focal spot with them except for thicker parts, and here one may need the large focal spot to shorten the exposure time. Worn screens obscure detail with a fine mottle of lighter areas, usually most evident at the edges of the film.

Screen contact if inadequate is recognized by a local area of poor definition. Where it is not due to improper mounting of the screens, a light-fogged margin will point to failure to place the film entirely between the screens or to incomplete closure of the cassette. Uniformity of screen contact can be readily tested by observing on a test film the image of household pins scattered on the surface of the cassette.

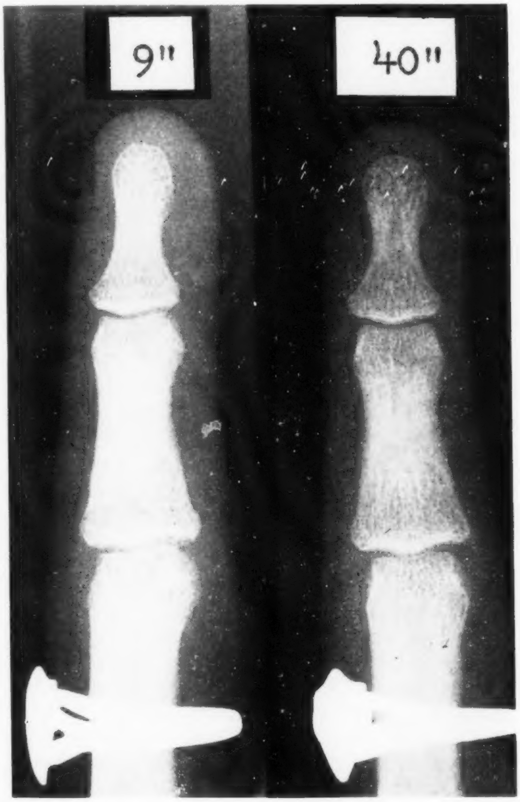

Figure 1 — Demonstration of the effect of a short object-film distance in relation to focal-film distance. Radiographs of a finger taken at 9" and 40" respectively show the same detail to the unaided eye.

C. Focal Spot Size

Focal spot size is closely allied to focal film distance and object-film distance in the geometry of image formation. The smaller the focal spot the better the definition. One may however use a large focal spot as effectively as a small one by increasing the target-film distance. If the focal spot size is doubled one will get equal definition by doubling the target-object distance.

D. Distance

Providing the penumbral unsharpness is below 0.1mm., one may recognize no degradation of definition with even very short target-film distances. For example, one may make radiographs of a finger at 9" and 40" respectively with no apparent change in definition. (Fig. 1) There is of course a difference but this is unrecognizable without magnification. With thicker tissues and larger object-film distances this manoeuver would give intolerably poor definition. A good rule to remember is that definition is constant for all focal-film distances providing the ratio of focal-object distance to object-film distance is maintained[4].

E. Exposure

Ordinarily exposure is thought of as having little effect upon detail. However, gross under-exposure may fail to record detail and over-exposure may hide detail by blackening the film to the point where it cannot be interpreted with conventional viewing. Further, such over-exposure may in the case of screens cause marked degradation of definition by irradiation of the image in the screens. Figure 2 illustrates this. Here a series of increasing exposures was given through uniform sized holes in a metal plate over a cassette. Good definition at the margins with a normal exposure is lost at the apertures that have been over-exposed and there is progressive increase in their apparent size.

F. Grain and Graininess

In the diagnostic field the resolution of conventional film is fairly uniform among the various brands offered. Grain size is important to resolving power, but one must couple this with contrast as a determining factor.

Grain and graininess are to be distinguished. As commonly used the word "grain" refers to the actual size of the grains of developed silver and these are too small to be recognized except with high magnification. Graininess refers to groups of grains which by aggregation and superimposition give rise to a lack of homogeneity of the image. The larger the grain size the greater the graininess expected. Over-exposure and over-development and thick emulsions contribute to graininess. Fortunately this is sufficiently low in X-ray film to be unimportant except where magnification is desired.

G. Parallax

Parallax in the images of the two emulsions of duplitized film is due to their separation by the film base and is seldom of any

consequence. It may be seen as a slight blur when the X-ray beam strikes the film at a very oblique angle such as used when making a Townes projection or in lateral views of the hip. It will be more evident on wet swollen film.

Figure 2 — Effect of over-exposure with screens. A series of increasing exposures was given through uniform sized holes in a metal plate. Note the spread of the image to produce blurred margins and apparent magnification.

II. OPACITY & III. SENSITIVITY

Opacity and sensitivity may well be considered together for they are closely related. Opacity in a film is the reciprocal of transmission and is always greater than 1. It can be defined as the ratio of light incident upon the film to the light transmitted. Density is the logarithm of the opacity. One may use any one of these three terms, opacity, transmission and density to express the light-stopping power of radiograph.

An opacity of 10 has a transparency of 1/10th and a density of 1. This is about the level of the middle tones of a radiograph.

The sensitivity or speed of a film may be expressed as the exposure in roentgens required to produce a certain density above that of the base material and fog level for a particular developer. Sensitivity parallels exposure fairly well. Failure to do so constitutes failure of the law of reciprocity. Theoretically this could happen when screens are used, for the exposure is then mainly by light waves to which reciprocity failure is linked[2].

Opacity of a particular film is affected by development and exposure. The latter is controlled by selection of kilovoltage, milliamperage, distance and time of exposure and is further affected by subject density and the use of grids, screens and filters. Development produces opacity in the film in relation to a time-temperature ratio, type of developer, agitation and relative exhaustion. Exhaustion can be measured by the comparison of test films with a standard made in fresh developer. A convenient way to do this is to expose a film through a wide step-wedge, (a step-like arrangement of medical journals will do) then cut it in strips which can be developed individually and compared day by day.

Film base opacity and the various types of fog add to general opacity and veil the legitimate image. There is more capacity for opacity in X-ray film than is ordinarily utilized. The limiting factors in the choice of maximum opacity are the strength of available illumination in view-boxes and eye comfort in viewing. Attention should be paid to the importance of glare in increasing apparent opacity. The exposed face of the regulation 14" by 17" view box is best covered when films smaller than this are examined.

The gain in speed to be expected with the use of screens is a variable amount dependent upon the type of screen (slow, par-speed and fast), the kilovoltage range and the density desired in the radiograph. As a rough guide, a factor of 15 may be used for par-speed screens.

IV. CONTRAST

Contrast may be defined as the difference in opacity between the lightest and darkest parts of a subject as recorded in a radiograph. A difference in opacity between areas in juxtaposition is essential for the recognition of detail. The abruptness of this change is important in interpretation.

There are seven major factors which influence contrast: A. KVP/Mas ratio B. Filtration C. Total exposure D. Development E. Screens F. Fog G. Viewing conditions.

A. KVP/Mas Ratio

In pre-television days it was common to confuse brightness with contrast. Nowadays the distinction is familiar to everyone who manipulates the dials. Control of contrast in ordinary photography is possible over a wide range by choice of film, lighting, exposure and development. In radiography regular films are fairly uniform in inherent contrast but one may use non-screen film if more is desired. More commonly a variation in this quality is obtained by manipulation of two factors in exposure — kilovoltage and milliampere-seconds. Increasing the KVP/Mas ratio leads to a lowering of contrast and by proper adjustment the level of density can be maintained.

B. Filtration

Filtration of the X-ray beam increases the effective kilovoltage by absorbing very soft radiation. The current trend is for the use of tube filtration of 2mm to 4mm of aluminum, mainly to reduce radiation to the patient. Filtration of the X-ray beam after passing through the patient is effected to some extent by the use of stationary or moving grids. Cassettes with lead intensifying screens as used with high kilovoltage techniques absorb some of the soft radiation.

C. Total Exposure

Contrast is decreased by under-exposure and over-exposure. With the first, the exposure may be at the threshold level for the sensitivity of the film, and the difference in response in areas of variable radiopacity is rather flat. With over-exposure, near-maximum blackening is reached in the rendition of all except very opaque objects in the path of the X-ray beam and there is generalized uniformity of recorded opacity. Moreover as indicated in the discussion of resolution, over-exposure causes film and screen irradiation and this lowers contrast by encroachment upon light areas. One should keep in mind the fact that an increase in contrast obtained by low kilovoltage techniques makes the proper exposure more critical.

D. Development

Development affects contrast to a moderate degree. With the usual strength of solutions, development for 3 minutes at 68° F. gives optimum contrast for the majority of work*. Additional contrast may be obtained by development for 5 minutes but shortly beyond this there will be an actual decline. Reduction of development below 3 minutes results in less contrast. Development time to produce optimum contrast and density is of course dependent upon temperature as well and for this one may refer to published data of the film manufacturers.

E. Screens

The use of screens increases contrast markedly. For certain uses this is desirable; for others the range may be excessive and it may be necessary to raise the KVP/Mas ratio to control it.

Figure 3 — Developer fog test. Top section in fixer only. Bottom section in developer and fixer. Densitometer readings .10 and .23 respectively.

F. Fog

Fog in its many forms is a veil of silver or silver compounds which may or may not lower contrast, depending upon whether it utilizes silver which would otherwise form the true image. Usually it does lower contrast and it always adds to the opacity of the film.

Films tend to develop fog if kept for long out of their sealed containers in a hot or humid atmosphere, and those used after their expiration date may show it even if properly stored. For a particular developer-film combination there is a certain amount of developer fog on fresh film. Figure 3 demonstrates

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** The practice of developing for five minutes at 68° has been much encouraged of late in the interests of obtaining maximum density and (near) maximum contrast in radiography, with corresponding reduction of patient dosage. This "full development" for five minutes is, in the opinion of the Editorial Board, to be encouraged. Ed.*

this in an X-ray film developed in total darkness for 3½ minutes. The film was suspended so that the upper portion remained out of the developer to give the density of the supporting base alone. The two, base density and developer fog are the cloud through which interpretation must be made.

Developer stain is distinct from the fog produced by unwanted reduction of silver. Developing solutions become progressively browner from oxidation and transfer this tone to the emulsion.

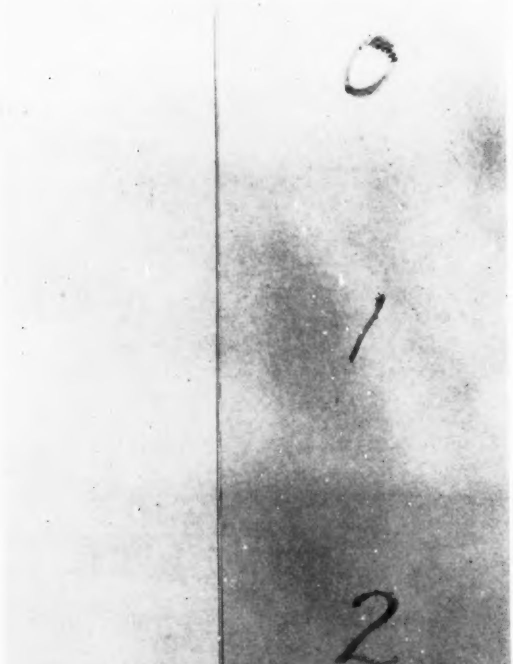

Figure 4 — Dark room light fog test. Two competitive films exposed side by side in steps for 1, 2, and 3 minutes. The area marked 0 had no light exposure.

Fog arises from many unexpected sources of radiation in the visible spectrum. Unsafe dark-room illumination is readily detected, once suspected. It is helpful to make a test by placing a film on the loading bench and uncovering successive portions for intervals increasing by ½ minute to the maximum of time films are ordinarily exposed to the dark-room lights (Figure 4). In comparing this type of fog in two competitive films one must discount developer fog and film base density which may be different in them. Further, one should in fairness use the particular light filter recommended by each manufacturer. A refinement of the above test which takes into account a possible priming effect is to make a low density X-ray exposure upon the films before making the experiment.

Previous X-ray exposure from storage near an X-ray source or near radioactive materials is seldom seen. Film cartons with metal bands incorporated in them provide ready identification of this source of fog.

A bit of radioactive material may find its way into the cardboard of which the film carton is made and give rise to small round opacities in developed films. These will be seen on the same portions of other films from the same box. Manufacturers are alert to this problem and have largely eliminated it by constant check on the sources of materials used in the making of paper and cardboard.

Secondary X-radiation causes a general fog and is controlled in many ways. Stationary or moving grids of various focal lengths and efficiency are available. The more effective ones require more care in centering and heavier exposures. Efficiency is determined by the grid ratio, an expression of the depth of the spaces between the metal strips in relation to their width.

Additional helps to control secondary radiation are found in the use of cones to limit the X-ray beam strictly to the area required for examination, and compression devices to reduce the thickness of tissues traversed. With magnification techniques in which the subject is a moderate distance from the film much secondary radiation is dispersed and does not reach the emulsion.

Back-scatter, which is secondary radiation emanating from objects beneath the film, is not often recognized as a source of curious shadows and slight general fog. This trouble may be eliminated largely by lead backing for non-screen technique. Some cardboard film holders have lead foil already incorporated in them.

G. Viewing Conditions

The apparent contrast is lowered if glare is introduced by excessive general illumination in the viewing room or by large clear areas in the film.

V. GRADATION

Gradation or scale is a quality defined as the ability to show small shades of differences in radiographic subject opacity. It is distinct from contrast; two films may show the same contrast from maximum black to the clearest area but a marked difference in the number of intermediate densities.

One might better appreciate scale by reference to comparison of the infinite gradations in pitch of a violin to the limited notes of a string instrument with frets. A closer parallel is in the comparison of a continuous tone picture to the limited range of tones (practically, only two) in a blueprint.

Everyone is familiar with the long scale of a transparency on projection with its multitude of tones from deepest black to dazzling highlights. A paper print of the transparency may be acceptably pleasing but it of necessity has a compressed scale limited by the lower range of reflection from the paper base compared to the high transmission of the transparency.

In conventional photography one has a choice of printing and enlarging papers of varying scale to suit the scale of the negative to produce the most pleasing print. In radiology the process stops at the negative stage and further manipulation is not undertaken. One must understand however that an X-ray film has a built-in capacity for scale which may or may not be exploited.

Development short of the optimum will reduce the scale, for the maximum black may not be reached. The use of screens shortens the scale considerably. Since development is usually standardized by time and temperature, and the use of screens obligatory for most exposures, the usual method of modification lies in the choice of the KVP/Mas relationship. Higher kilovoltage (and higher effective kilovoltage from increased filtration) results in a lengthening of the scale.

VI. LATITUDE

Latitude refers to the range of variation in exposure permissible without changing contrast or tone reproduction. It is distinct from gradation. Wideness in latitude has a parallel in the tonal range of a piano with five octaves compared to one with seven. A thin emulsion may have less latitude than a thick one although within its limitations it may have the same scale. Regular X-ray film has sufficient of this quality to take care of a rather wide range of exposures. Latitude is reduced by low kilovoltage techniques and other factors which increase contrast.

Inherent film latitude with respect to exposure is distinct from latitude dependent upon development. With suitable exposure most films may be developed for 3 minutes or for 5 minutes with the expectation that each technique will produce satisfactory results.

VII. PHYSICAL QUALITIES

The important physical qualities may be listed as follows:
a. Surface texture, b. Tone, c. Dimensional stability, d. Thickness, e. Flexibility, f. Size, g. Flammability, h. Permanency.

The smooth moderately glossy surface texture of radiographic films is well accepted in spite of the tendency of this to make them slither annoyingly from the film envelope. There was a time when the surface of films was somewhat granular, an advantage in reducing surface reflections but giving an unpleasant gritty sensation in handling.

The tone of a radiograph is determined by that of the film base and developed emulsion. Present day base color is blue and this combined with the neutral black tones of the developed image gives a satisfactory appearance. Among viewers there is a wide variation in the effect of color on mood. Blue tones are generally considered colder and fresher than yellow which to some people is suggestive of deterioration and fading when used for pictures, presumably because pictures and newspapers yellow with age. Rarely there appears an advocate of the use of colored lights such as red or yellow in view boxes for a fancied improvement in recognition of detail.

Dimensional stability, thickness and flexibility are other physical qualities which are of little concern to the radiologist as they are presently uniform among the various brands and very satisfactory. The flammability of modern cellulose ester film is about the same as newsprint in contrast to the dangerous cellulose nitrate formerly used. Sizes of films offered are generally very satisfactory. There have been attempts to introduce new sizes but since this would necessitate expensive modification of existing equipment it is not likely that changes will be made for many years.

Many radiographs are discarded in 5 to 10 years and during this time they will suffer no deterioration if they have been properly processed in the fixing and washing baths. Storage for longer periods is well tolerated.

VIII COMPOSITION

Composition refers to the choice of subject and the rendition of its arrangement within the limits of the radiograph. It may be considered under the headings: A. Artistic principles, B. Perspective, C. Magnification, D. Distortion.

A. Artistic Principles

Anyone who has sorted films for an exhibit will appreciate the importance of the artistic side of composition to quality. Radiographs which are functionally satisfactory for the daily routine may make a poor showing in an exhibit. Where a group of films of one region is being shown, uniformity in positioning, in method of marking and masking, and in density and contrast is desirable. Identification marks should be legible, neat and well placed.

B. Perspective

In radiography one attempts to represent a three dimensional object on a two dimensional plane. The appearance in the radiograph of the parts of the object with respect to their true position and dimensions is known as perspective. If the film is placed so that the central ray strikes it vertically then it will record the subject just as the eye would see it if endowed with penetrating powers, and the perspective will be correct if the radiograh is viewed at the taking distance. In other words the focal spot "sees" the object as would the eye if placed in its position. Viewing the film at distances other than that used for taking it introduces a viewing distortion. In practice one is usually not aware of this and films exposed at distances of 25" to 72" are examined at any convenient distance with no appreciation of the difference.

Where the film is placed obliquely with respect to the X-ray beam it should in theory be interpreted in an oblique position but here again perspective is dominated by other considerations and this practice is not worth following. With stereoscopic views however there is more reason for paying attention to perspective for one is attempting to create a three dimensional portrayal of the subject. Perspective will be incorrect unless the two films are properly orientated on the stereoscope. McGrigor[3] has determined that there are 128 different ways to place the films of which only one permits correct stereoscopic rendering. They will even then not be fully accurate in appearance unless viewed at the taking distance but this factor is usually ignored.

C. Magnification

The true shadow (umbra) of any part which is larger than the focal spot is recorded with enlargement. The degree of magnification which is a purely geometrical problem is expressed by the formula:

$$\frac{FFD}{FFD - OFD} - 1 \times 100 = \text{Per Cent Magnification}^{1}.$$

where FFD is focal-film distance and OFD is object-film distance.

An apparent but unreal magnification may arise from lateral spread of the image on screens as discussed in reference to "detail". Similarly one may have an apparent reduction in size if one is dealing with radiopaque subject areas surrounded by radiolucent areas.

D. Distortion

Distortion is always present in a radiograph but the amount of this varies in different parts depending upon the position of the subject densities with respect to one another. This coupled with variable magnification dependent upon distance gives a misshapen representation of the structures in the path of the X-ray beam.

Distortion other than magnification cannot be expressed in a formula but the extent of it can be readily appreciated by drawing the path of the X-ray beam to scale. In the absence of a stereoscopic pair of films it may be necessary to take multiple single views to show clearly the spatial arrangement of the various parts of the subject. It is then appreciated how readily one can be misled in reporting one structure medial to another when its true position is lateral, superior when it should be inferior and larger when it is actually smaller.

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CLINICAL STAGE CLASSIFICATION OF MALIGNANT TUMOURS OF THE BREAST ("T.N.M. System")

The Committee on Clinical Stage Classification and Applied Statistics of the International Union Against Cancer has now developed a special data sheet for the trial of the proposed method of staging breast cancer. Copies of this data sheet and instructions for its use are available on request from the Ontario Cancer Treatment and Research Foundation, 69 Bloor Street, East, Toronto (Dr. A. H. Sellers, Chairman of the Committee on Records and Statistics).

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